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**Characteristics of a 240 to 400 MHz 4-inch Depth
Ridged-Cavity Cross-Slot Antenna
on a Curved Ground Plane**

Electronics Research Laboratory
The Ivan A. Getting Laboratories
The Aerospace Corporation

20 January 1977

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FOR THE COMMANDER


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PREFACE

This antenna is one of two (slot and dipole) that were developed for a series of aircraft flight tests to evaluate the performance of aircraft antennas in a satellite-to-aircraft communication link. The slot antenna has not been flown at the time of this writing while the dipole antenna has been flown and the results described in a report by L. R. Nawman and H. E. King, "Flight Test Evaluation of a 240 to 400 MHz Cavity-Backed Cross Open-Sleeve Dipole Antenna," Air Force Avionics Laboratory and The Aerespace Corporation, Electronics Research Laboratory, SAMSO TR-75-241, 10 October 1975.

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I. INTRODUCTION

This report describes the electrical and mechanical characteristics of a full-scale wideband, circularly-polarized, hemispherical-coverage antenna operating in the 240 to 400 MHz frequency range (1.67:1 frequency ratio). The antenna is a ridged-cavity crossed-slot antenna that was originally designed for flush-mounted installation on an aircraft. The cavity dimensions were constrained to be within a 33-in. square area and a 4.18-in. depth. The feasibility of this antenna was established in Reference 1. Measurements using a half-scale model antenna have demonstrated its wideband electrical characteristics. The cavity is $< 0.085\lambda$ deep at 240 MHz (0.142λ at 400 MHz) and has a square base dimension of 0.672λ at 240 MHz. The present study is concerned with the development of a full-scale antenna for a potential in-flight propagation test employing an aircraft-to-synchronous satellite communication link. The antenna was to be mounted atop a KC-135 type aircraft and covered with a radome.

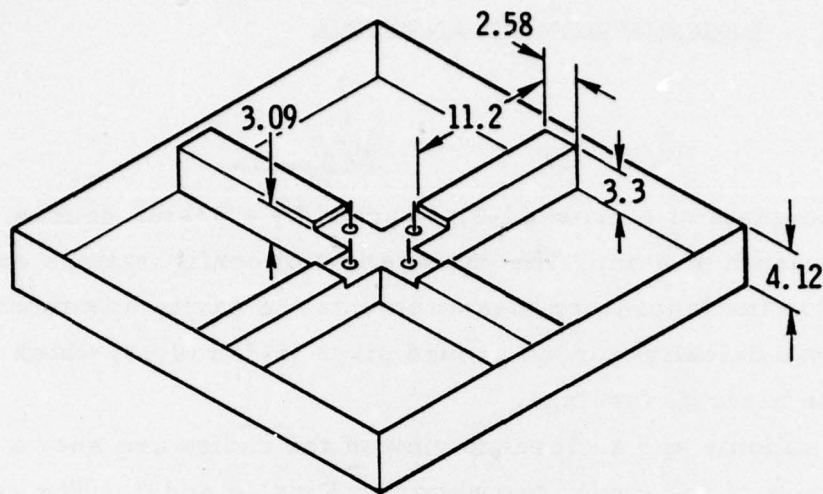
II. DESCRIPTION OF ANTENNA

The antenna consists of a crossed-slot backed by a 33-in. square ridged cavity with a depth of 4 in. The cavity and slot configurations are shown in Fig. 1. For the laboratory measurements the cavity was mounted on a 9.5 x 9.5 ft. cylindrically-curved ground plane (6-ft radius) which simulated a section of the aircraft fuselage.

The antenna, radome and a close-up view of the cavity are shown in Figs. 2 and 3. Details of the cavity are shown in Figs. 4 and 5. The nominal dimensions of the ridges and slots were established from a previous half-scale antenna development (Ref. 1). There are many design parameters one can vary through the use of the ridges and slot configurations. For the full scale antenna, vernier adjustments of the ridge parameters were made to optimize the VSWR response.

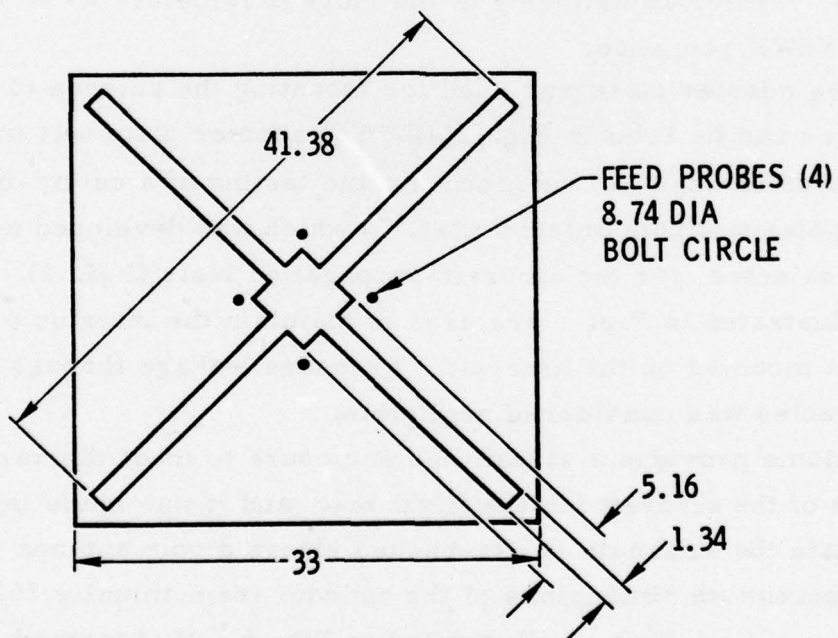
A square adapter plate was used for mounting the antenna to the curved ground plane as can be seen in Fig. 2(a). The adapter plate was made such that it could also be used for the mounting and testing of a cavity-backed, crossed open-sleeve dipole antenna (Ref. 2) which was developed as an alternate antenna, but selected, for the aircraft-propagation tests (Ref. 3). The mounting sleeves as illustrated in Fig. 5 are used to maintain the interior pressure when the antenna is mounted on the aircraft. Pressure leakage through the connectors and coaxial cables was considered negligible.

The radome provides a streamline enclosure to meet the aerodynamical requirements of the aircraft for the flight test, and it was made large enough to accommodate the alternate cavity-backed sleeve dipole antenna mentioned above. The maximum dimensions of the radome are nominally 76.5 in. long x 55 in. wide x 8.4 in. high as illustrated in Fig. 6. It is formed by 9 layers of 10 oz. fiberglass cloth impregnated with epoxy resin, resulting in an overall thickness of approximately 0.143 in. The weight of the radome is 30 lbs.



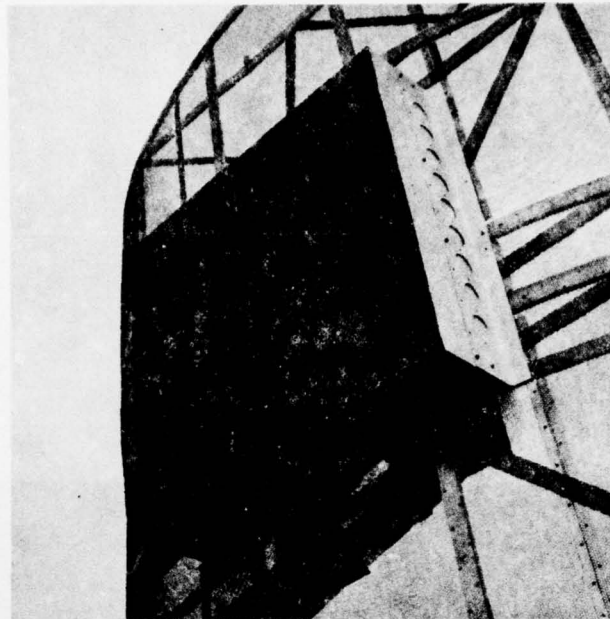
CAVITY WITH RIDGE

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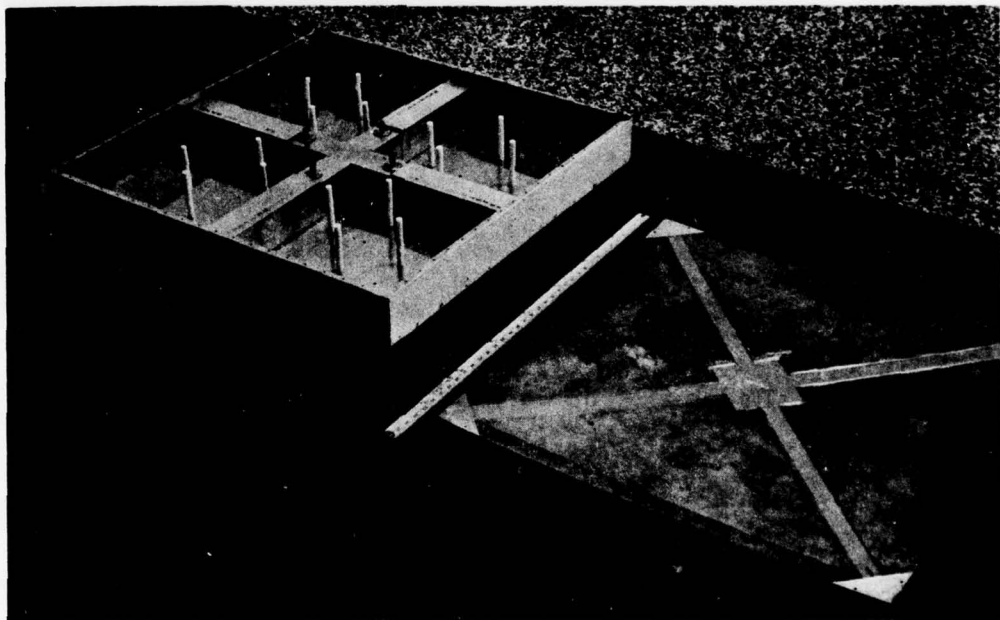


SLOT CONFIGURATION

Fig. 1 Basic Cavity and Slot Configuration



(a) Antenna mounted on 9.5 x 9.5 ft curved ground plane (6-ft radius) for RF measurements



(b) Inside view of cavity and slot configuration

Fig. 2. Ridged-Cavity, Crossed-Slot Antenna

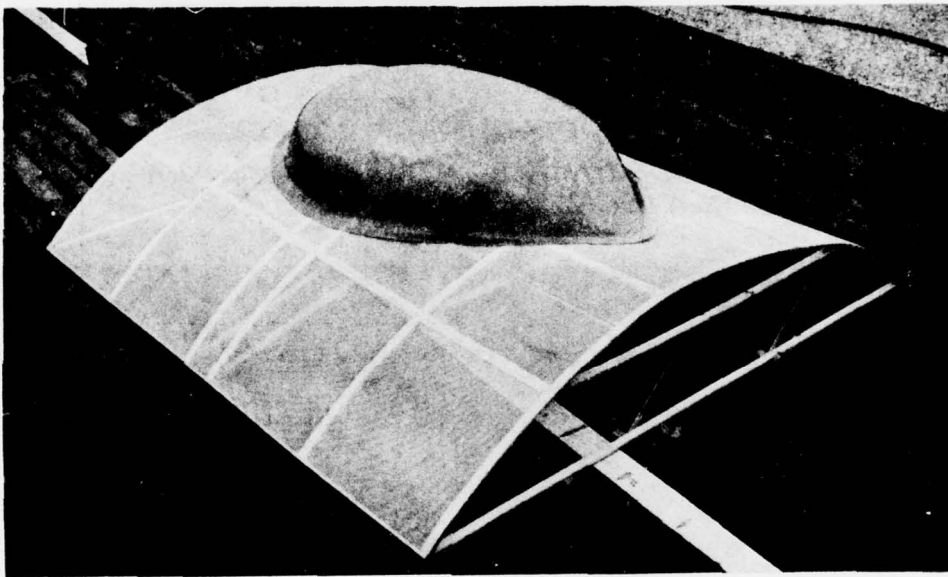
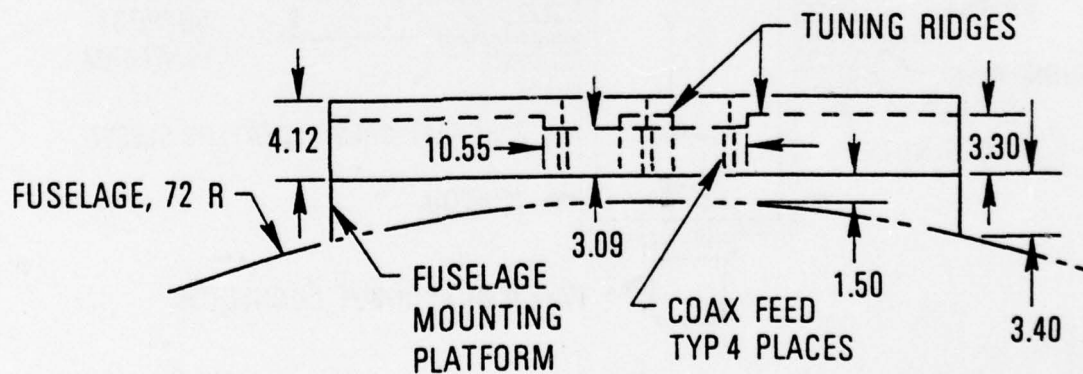
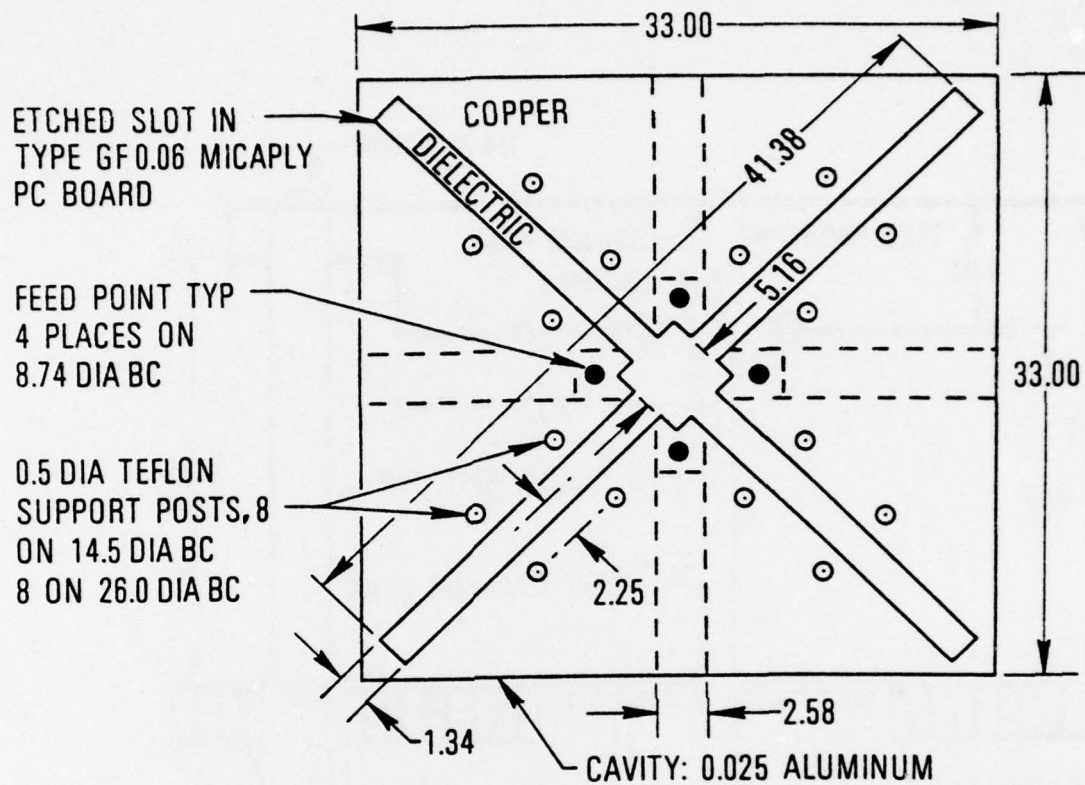


Fig. 3 Radome Mounted on Cylindrical Surface



ALL DIMENSIONS IN INCHES

Fig. 4 Ridged Cavity and Crossed Slot Details

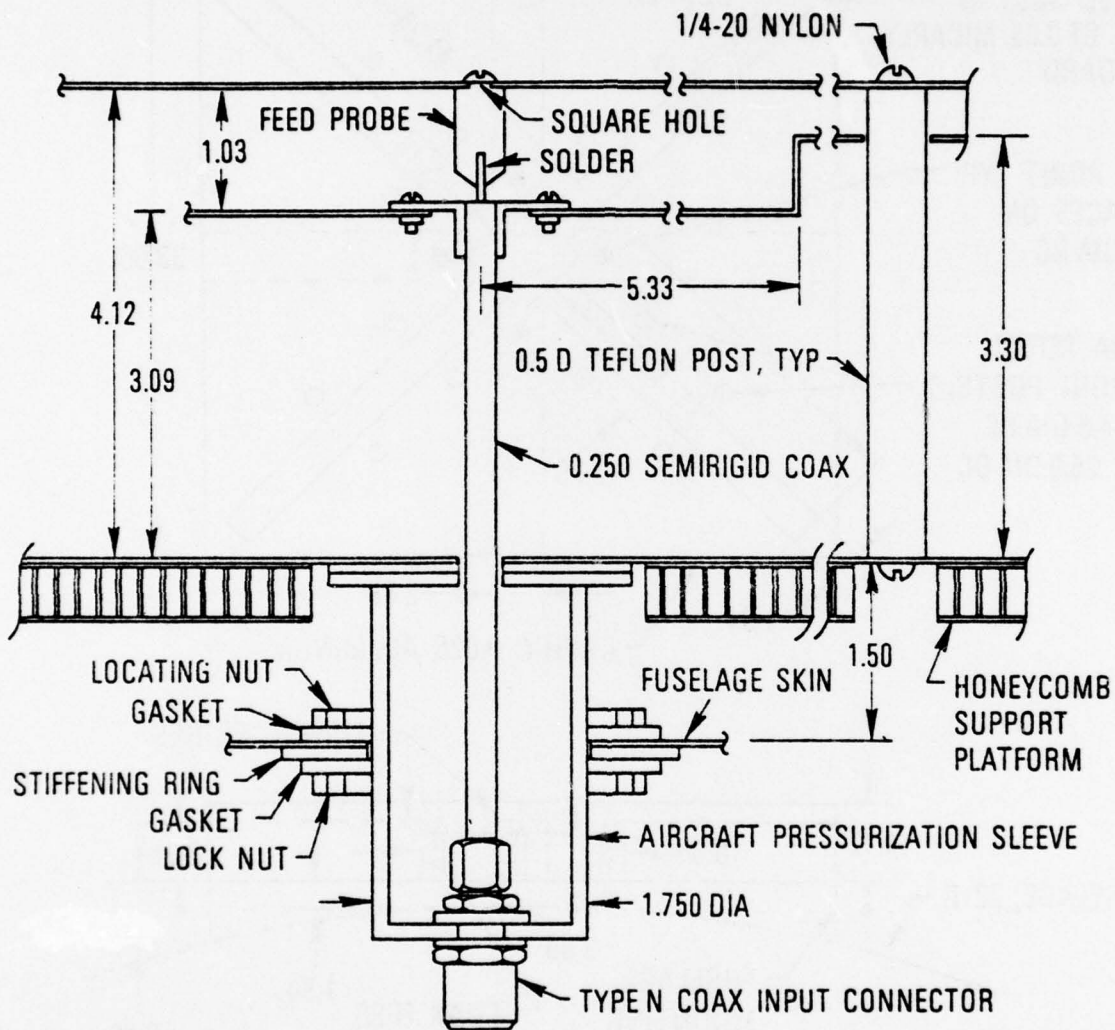


Fig. 5 Probe and Feed Point Details

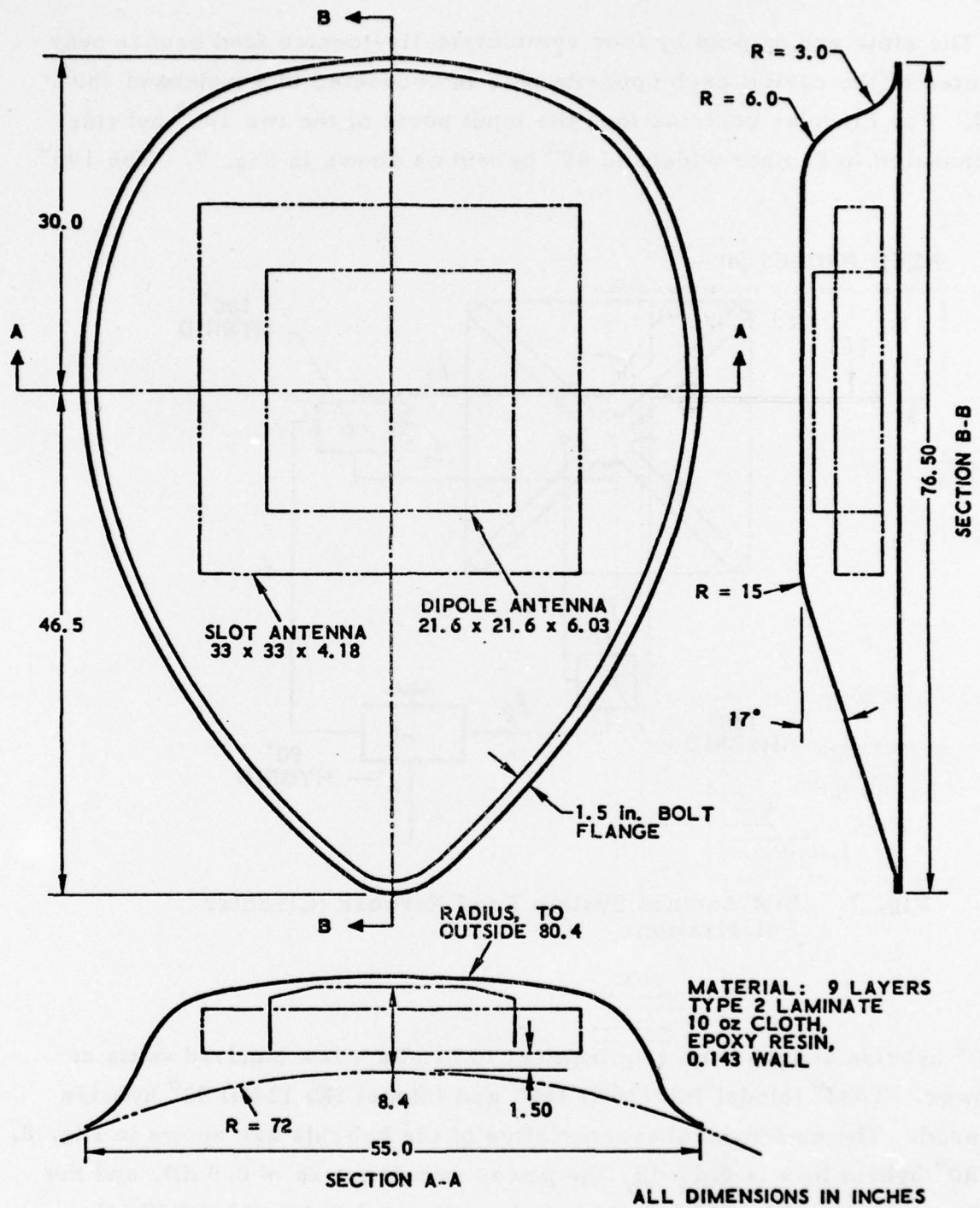


Fig. 6 Sketch of Radome

The slots are excited by four symmetrically-located feed probes near the center of the cavity; each opposite pair is connected to a wideband 180° hybrid. For circular polarization, the input ports of the two 180° hybrids are connected to another wideband 90° hybrid as shown in Fig. 7. The 180°

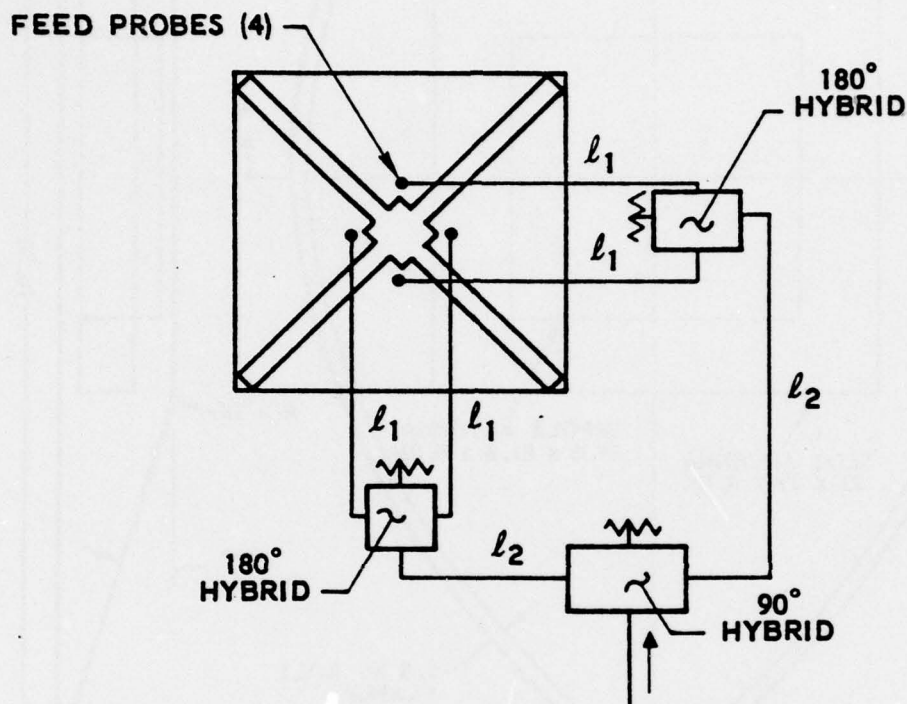
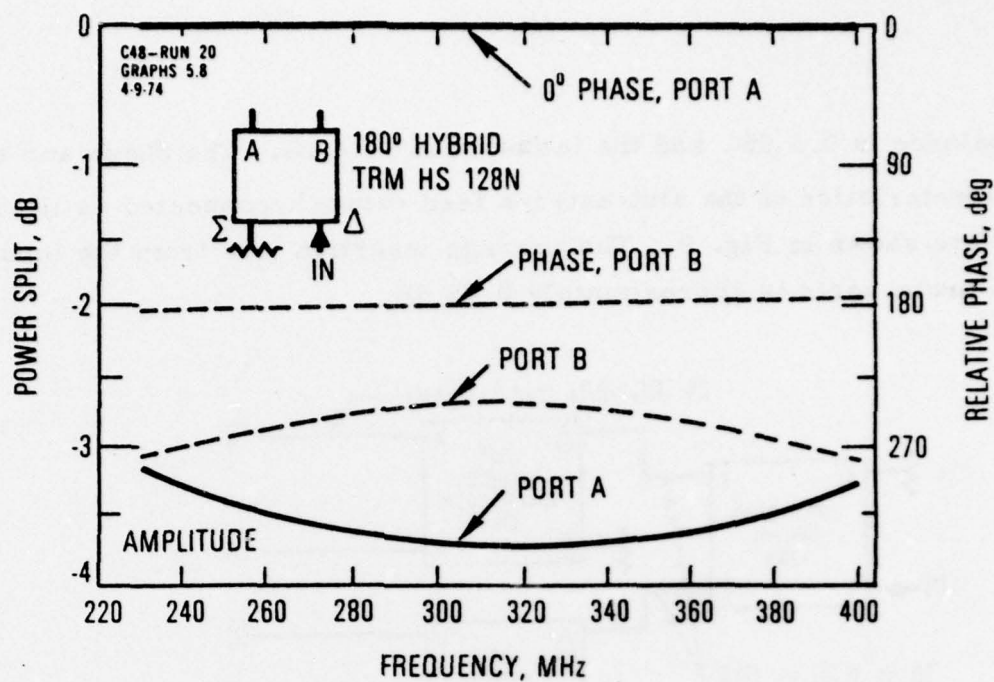


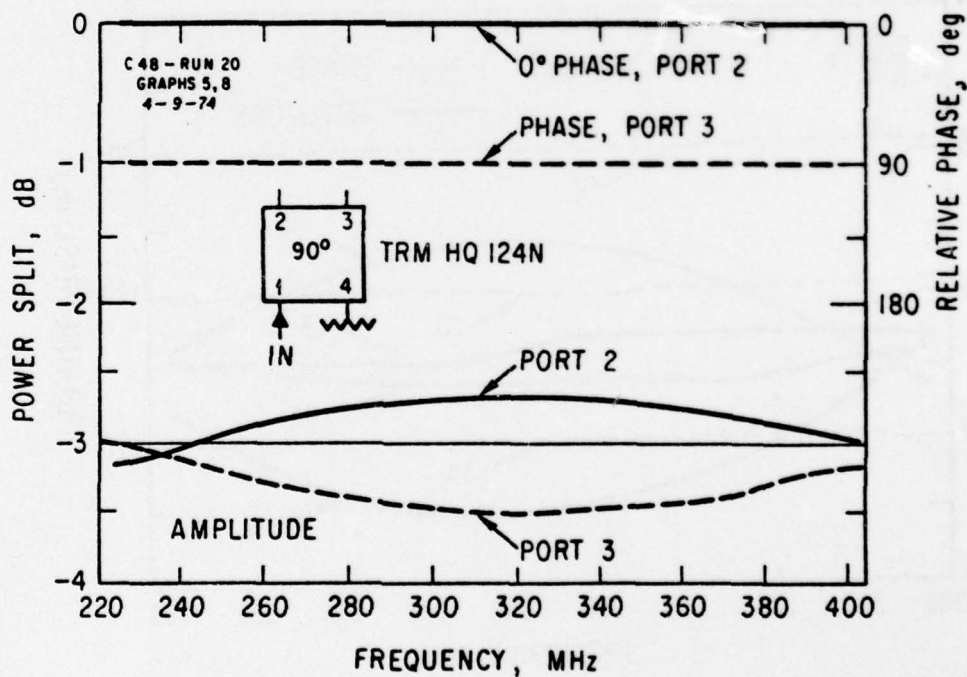
Fig. 7 Slot Antenna System Feed Network (Circular Polarization)

and 90° hybrids also had the requirement to handle a few hundred watts of RF power. TRM* (Model HS-128N) 180° and (Model HQ 124N) 90° hybrids were used. The measured characteristics of the hybrids are shown in Fig. 8. The 180° hybrid loss is 0.17 dB, the power imbalance is < 0.5 dB, and the isolation > 20 dB. The 90° hybrid loss is estimated to be < 0.10 dB, the

* Technical Research and Manufacturing, Inc.



(a) 180° Hybrid



(b) 90° Hybrid

Fig. 8 Hybrid Insertion Loss and Phase Characteristics

power imbalance is 0.5 dB, and the isolation is >24 dB. The phase and amplitude characteristics of the slot-antenna feed network, connected as illustrated in Fig. 7, are shown in Fig. 9. The average insertion loss from the input port to the probe ports is approximately 0.43 dB.

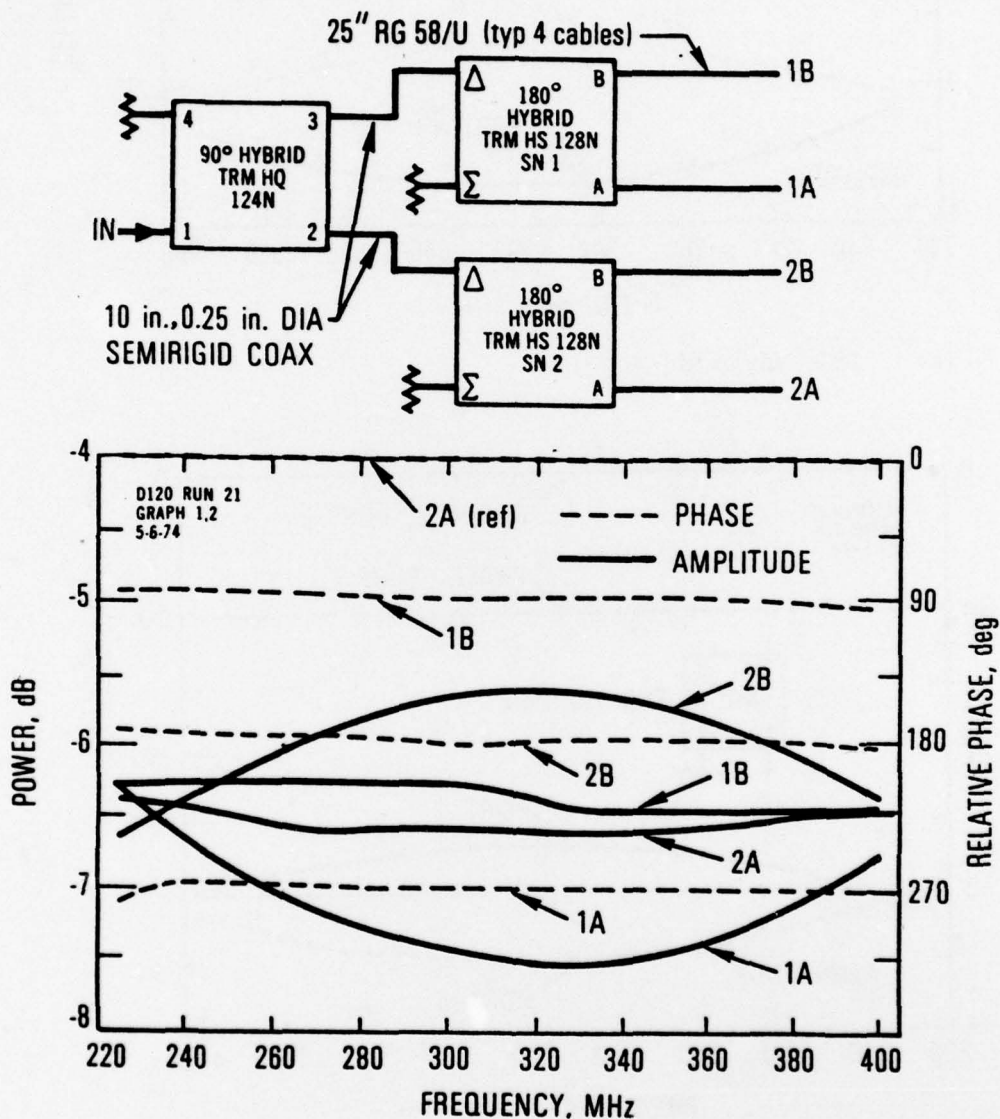


Fig. 9 Amplitude and Phase Characteristics of Feed Network

III. EXPERIMENTAL RESULTS

A. VSWR

Swept-frequency VSWR measurements were made for a variety of slot and ridge configurations using the half-scale model results as the baseline design (Ref. 1). Figure 10 represents the VSWR response of the configuration chosen for the full-scale antenna and the dimensions are detailed in Figs. 4 and 5. The VSWR response was recorded with the antenna connected for linear polarization (i.e., two oppositely located probes were connected to a 180° hybrid, and the other two probes were terminated in 50-ohm loads). The measurements were performed with two identical dual directional couplers inserted between the feed probes and the two output ports of the 180° hybrid. In this manner, the true VSWR of each feed probe, hence the slot, was obtained. The VSWR characteristics of the individual feed probes are essentially identical. Figure 10(a) illustrates the envelope of the VSWR spread. The VSWR at the input to the 180° and 90° hybrids are shown in Fig. 10(b).

B. PATTERNS

Radiation pattern measurements were made with the antenna mounted on the 9.5 ft x 9.5 ft cylindrically curved ground plane (6-ft radius). The coordinate system for the antenna is defined in Fig. 11. The slots were con-

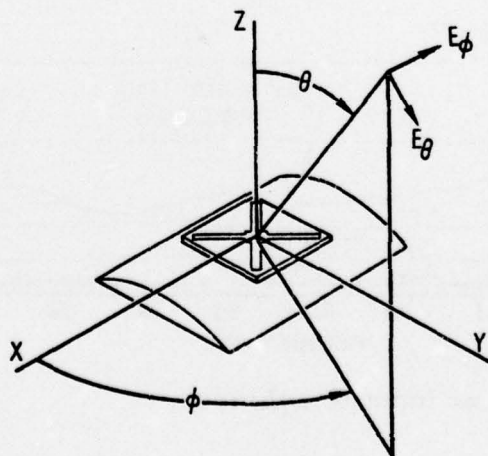
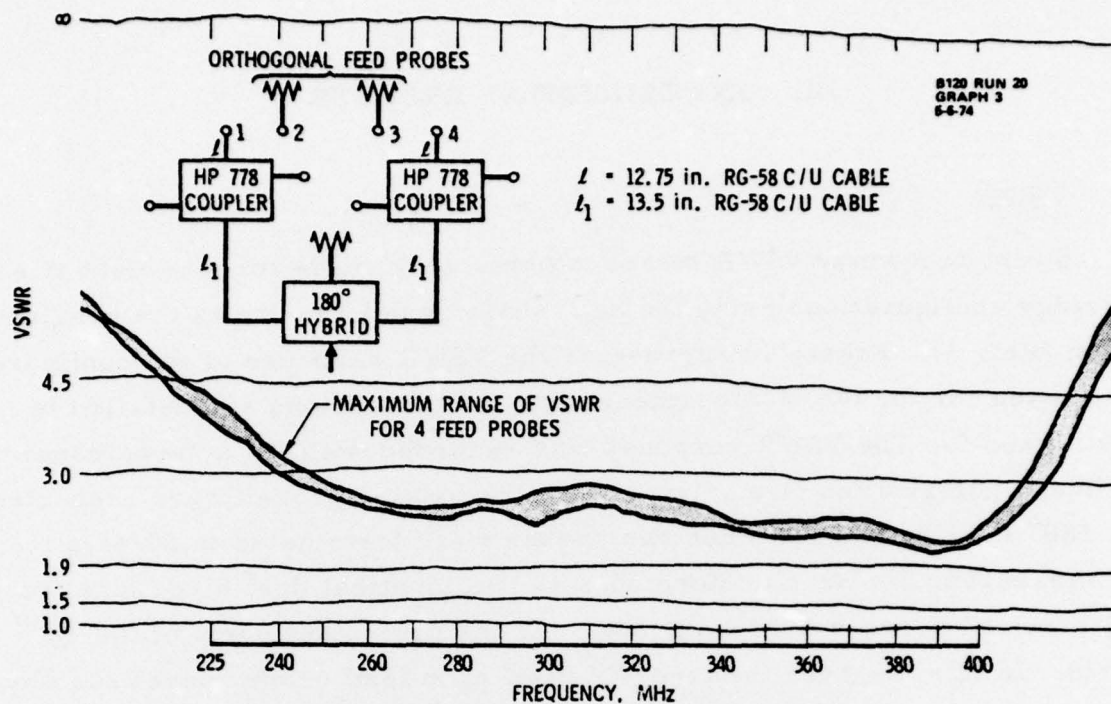
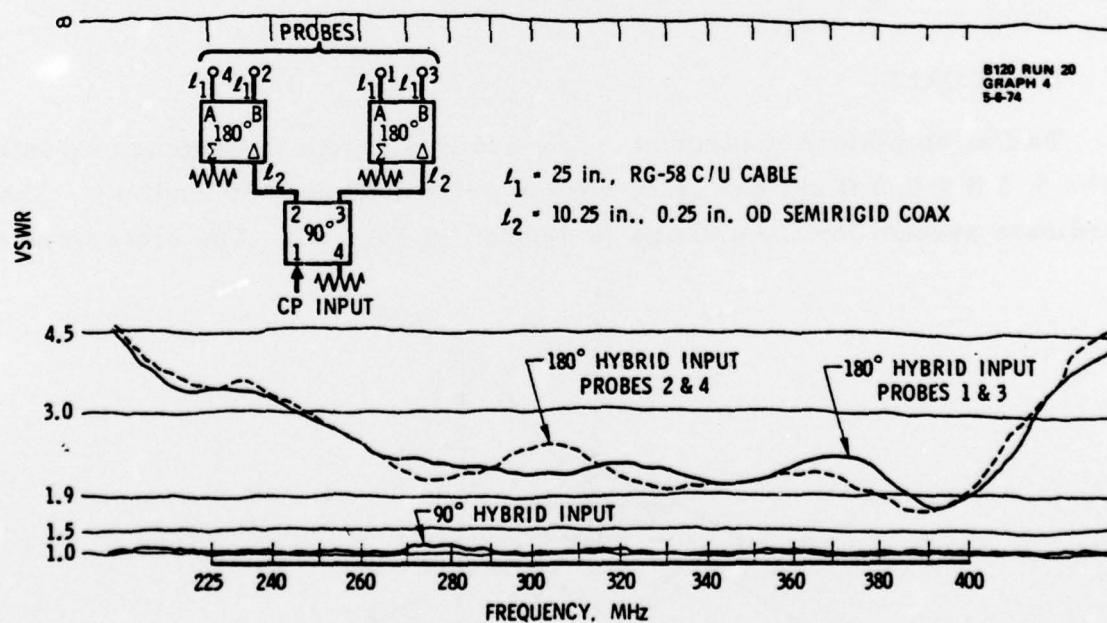


Fig. 11. Coordinate System for Pattern and Gain Measurements



(a) VSWR of individual probes



(b) VSWR at input to hybrids

Fig. 10 VSWR characteristics of the ridged-cavity, crossed-slot antenna.

nected for circular polarization and the antenna patterns were recorded with a rotating linearly-polarized source. Patterns were recorded in the two principal ($\theta = 0^\circ$ and 90°) planes and the $\theta = 45^\circ$ plane for six frequencies (240, 249.1, 272, 302.7, 350 and 400 MHz). The patterns of Figs. 12 through 17 demonstrate the wideband pattern response of the antenna and provide an estimate of the pattern characteristics that can be expected when the antenna is mounted on the aircraft.

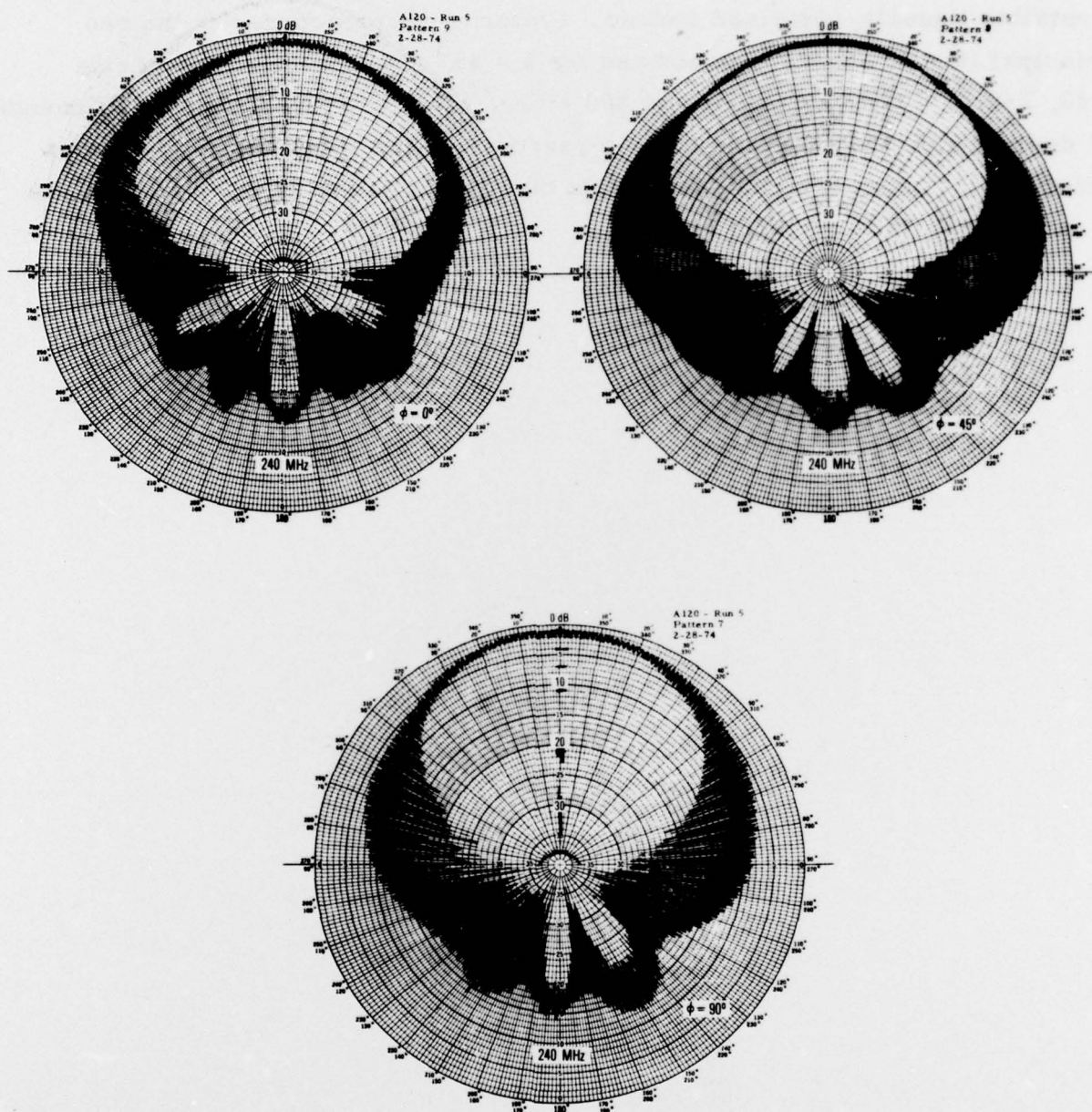


Fig. 12. Radiation patterns of cavity-slot antenna, 240 MHz

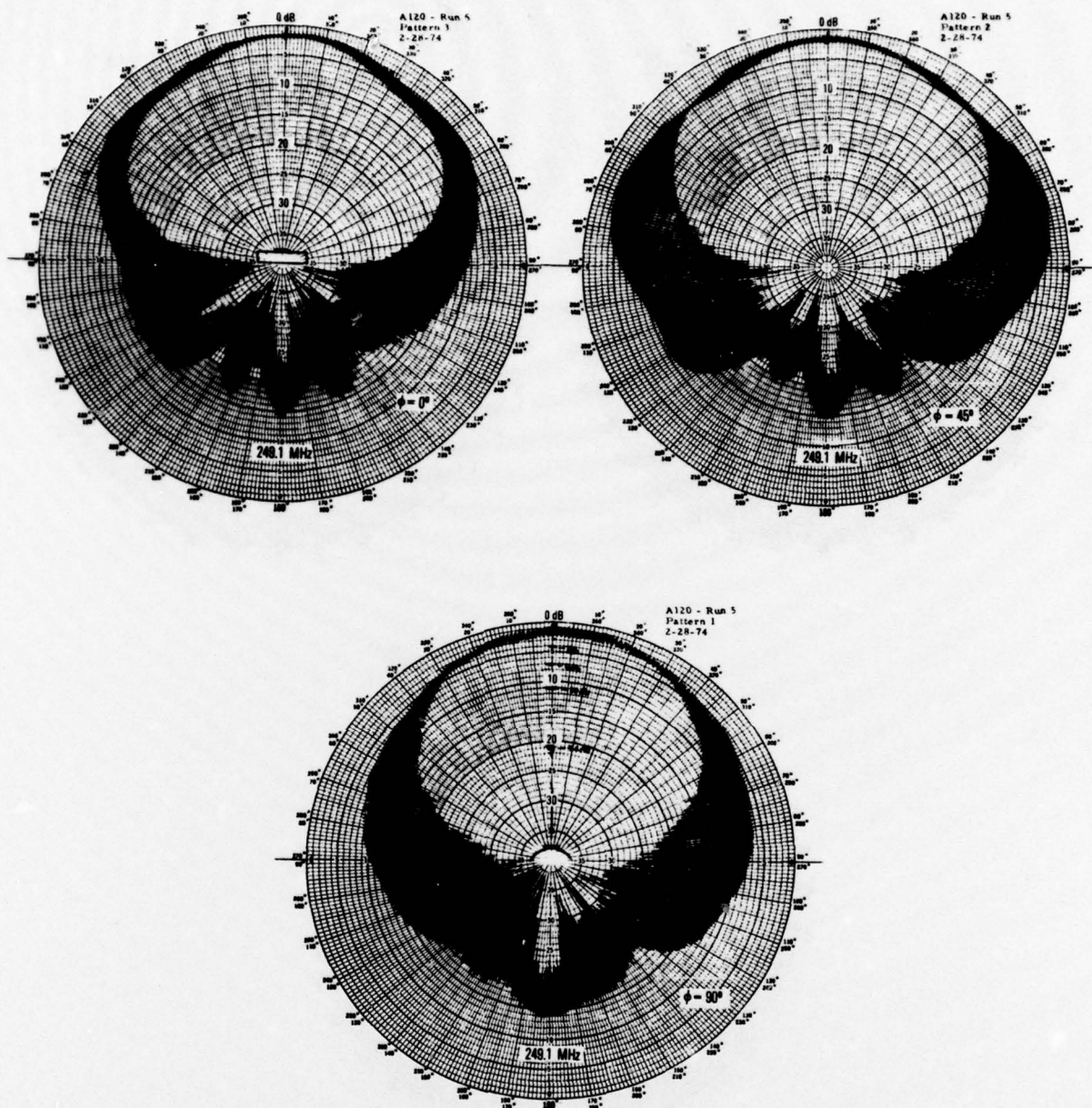


Fig. 13. Radiation patterns of cavity-slot antenna, 249.1 MHz

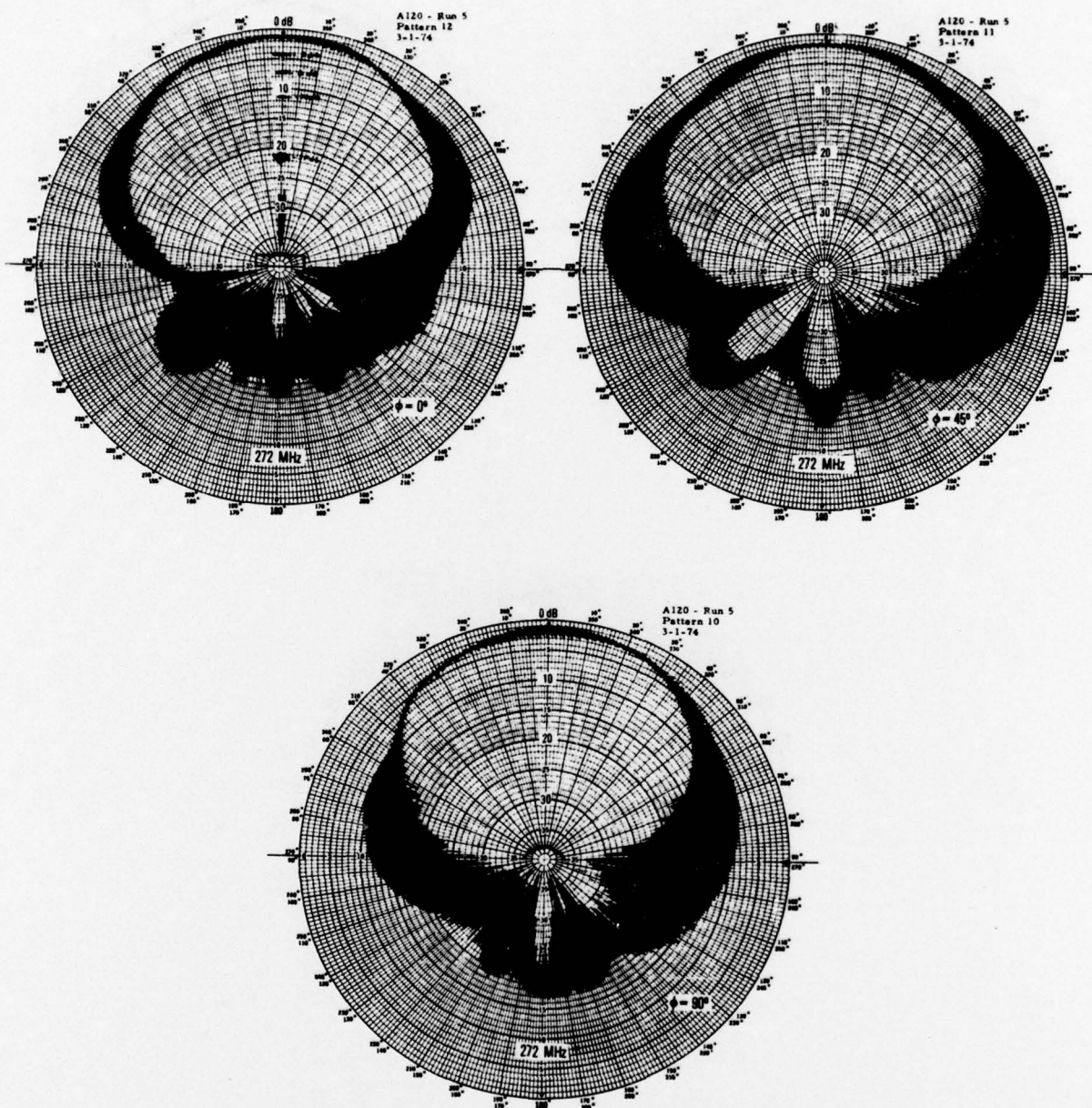


Fig. 14. Radiation patterns of cavity-slot antenna, 272 MHz

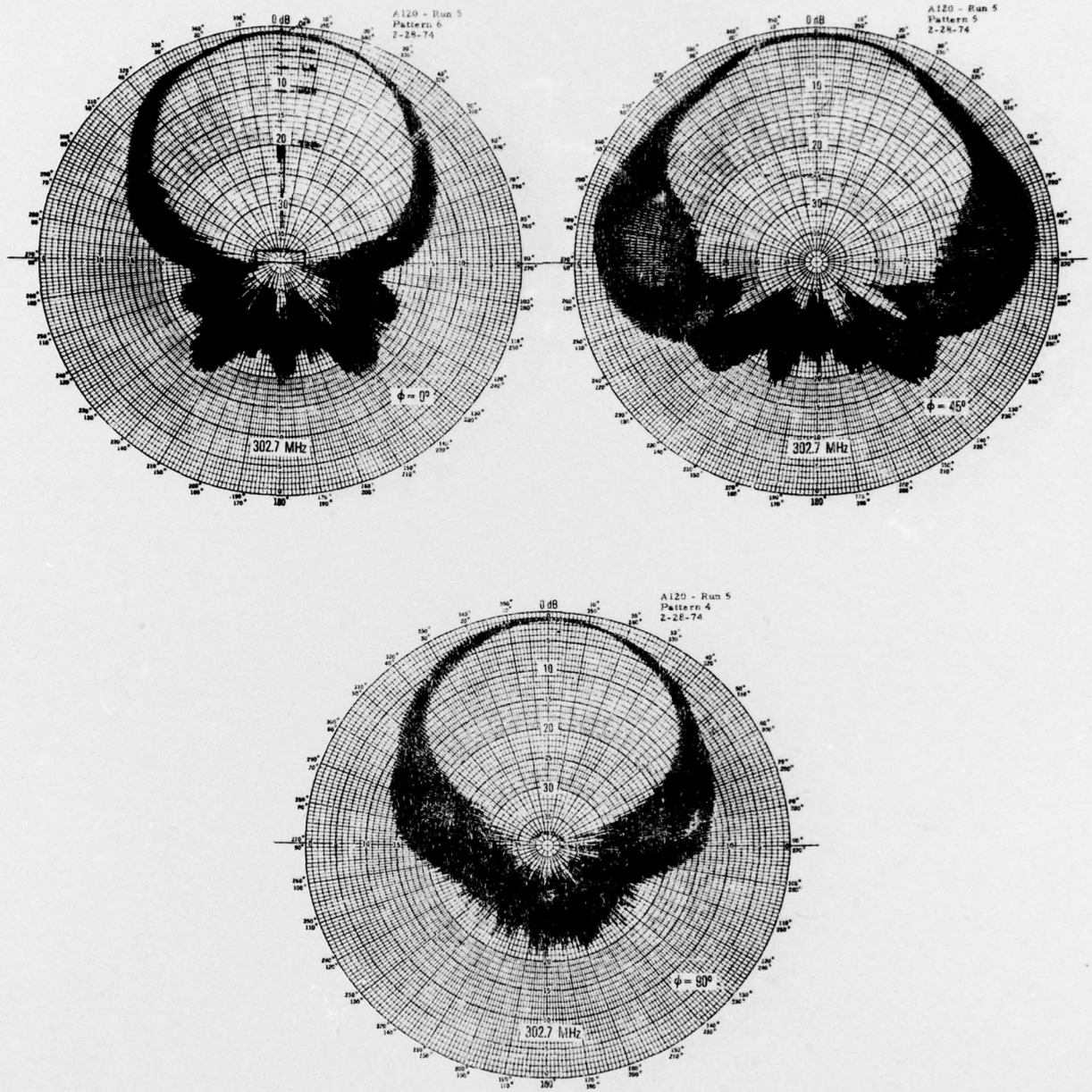


Fig. 15. Radiation patterns of cavity-slot antenna, 302.7 MHz

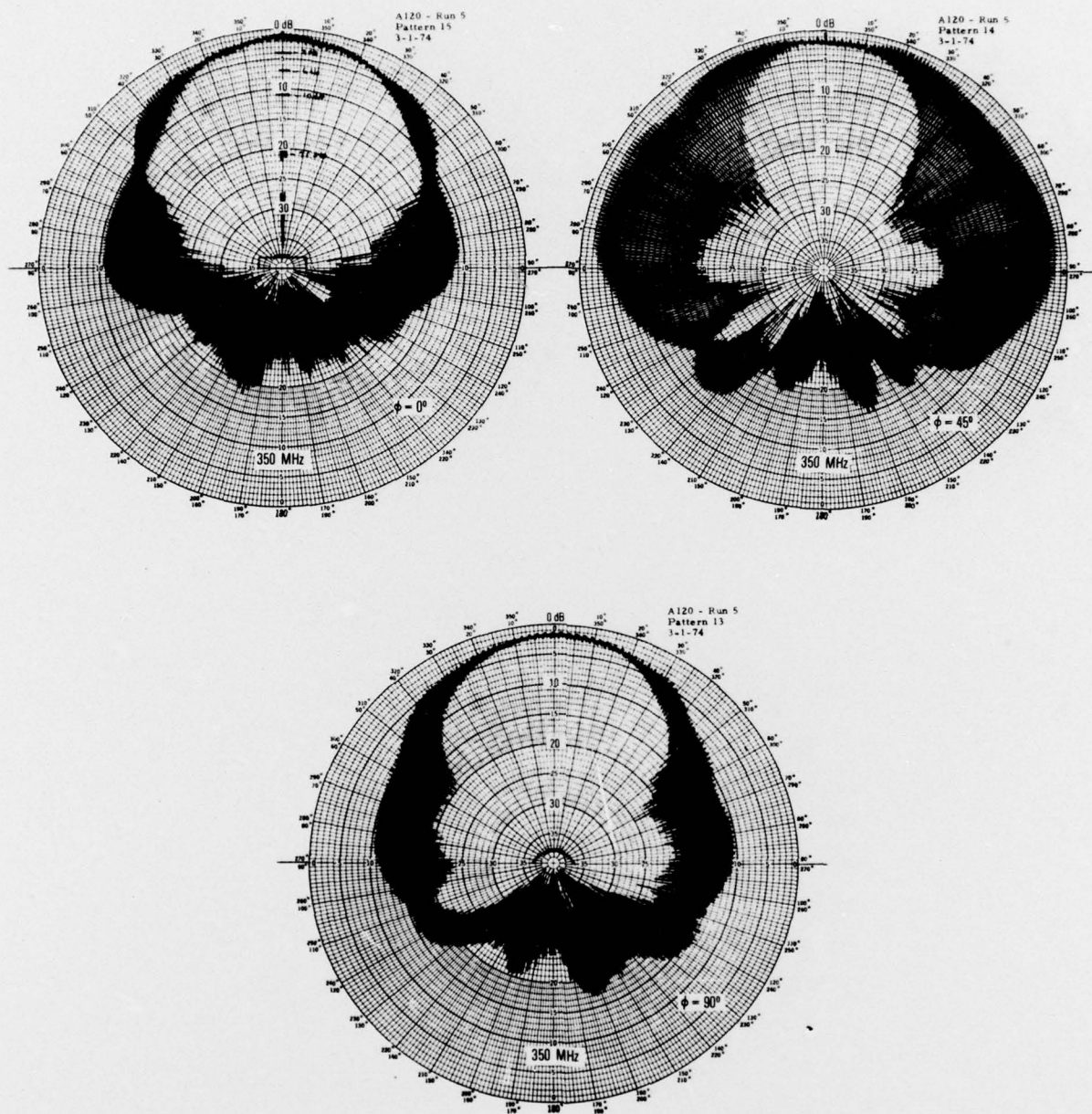


Fig. 16. Radiation patterns of cavity-slot antenna, 350 MHz

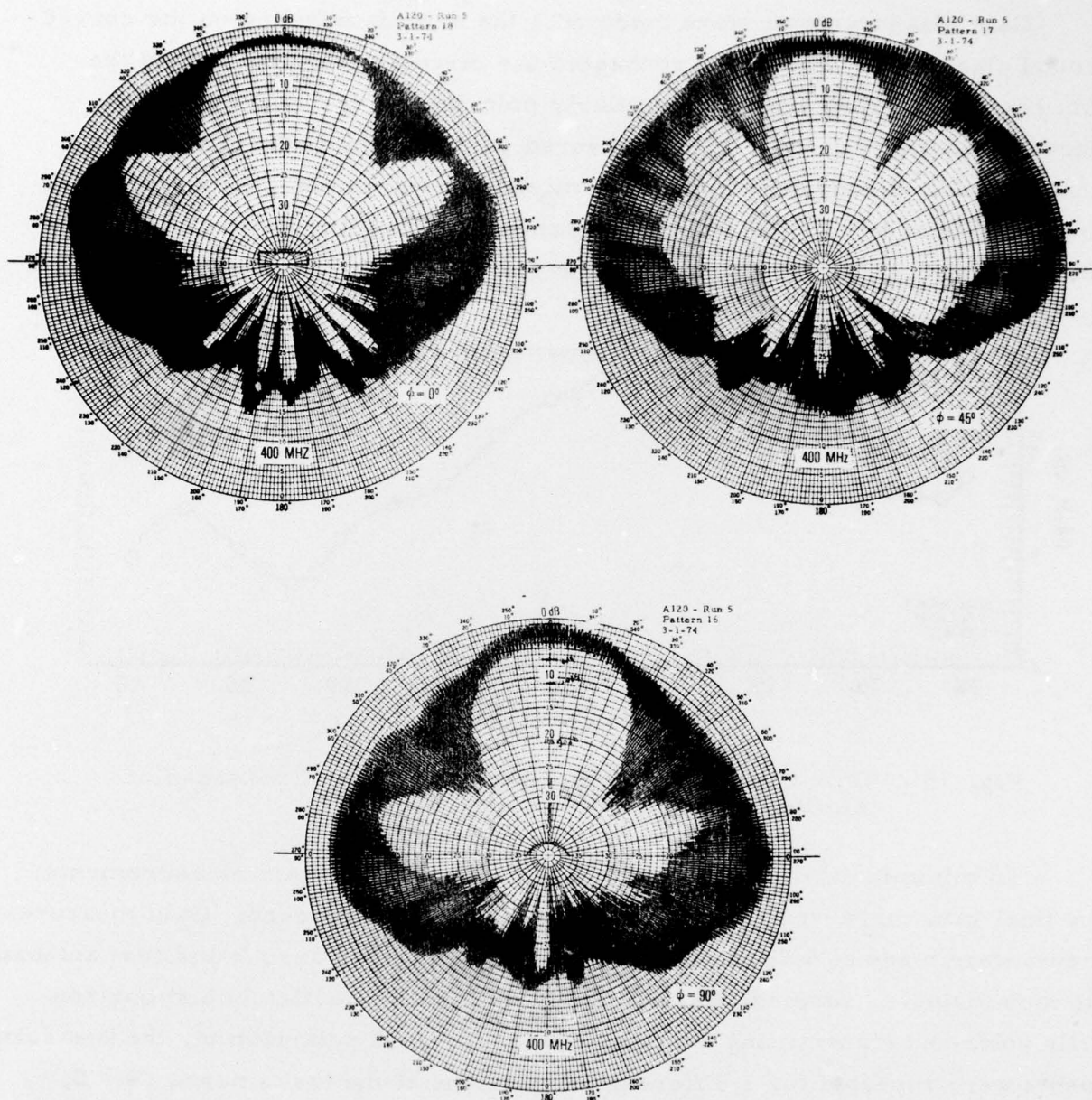


Fig. 17. Radiation patterns of cavity-slot antenna, 400 MHz

C. GAIN

Gain measurements were made with the antenna mounted on the curved ground plane. The slots were connected for circular polarization and the gain results are referred to a circularly polarized source and measured along the Z axis (Fig. 11). The measured gain of the antenna is shown in Fig. 18 and it includes the impedance mismatch losses and the losses of a 25-in. length of RG-58C/U cable (approximately 0.1 dB insertion loss), the 180° hybrid (0.17 dB insertion loss) and the 90° hybrid (< 0.1 dB).

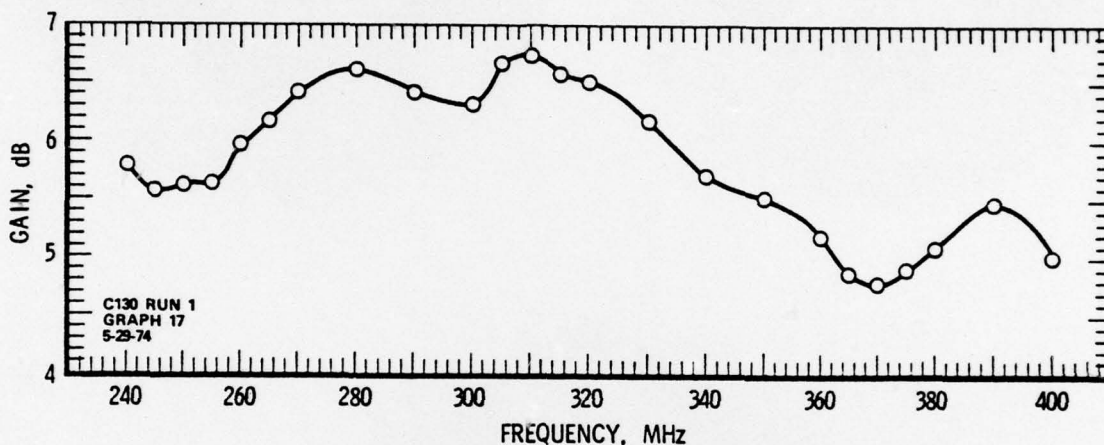


Fig. 18 Gain Characteristics of Ridged-Cavity, Crossed-Slot Antenna

To minimize the effects of multipath errors in the gain measurements, the final gain curve was determined from a lengthy procedure. Gain measurements were made at 5 different distances between the transmit and test antennas. At each distance, readings were obtained with both a vertically and horizontally polarized transmitting antenna. Also, for each polarization, the measurements were repeated for 3 different orientations of the test antenna ($\theta = 0^\circ$, 45° , and 90°). Data was recorded by a swept-frequency method using an HP network analyzer. At each of the frequencies selected for data reduction from the swept-frequency gain curves, the gain* was computed and all the gain

* Included corrections for axial ratio loss.

values were averaged to derive the antenna-gain curve of Fig. 18. The maximum deviation of data points from this mean gain curve is 1.0 dB, and on the average the deviation is 0.5 dB over the frequency band. This deviation is attributed to multipath, instrumentation and human errors.

The reference (standard gain) antenna was a wideband corner-reflector antenna^{*} fed with an open-sleeve dipole capable of operation over the measurement frequency range (Refs. 4-5). The corner reflector antenna was calibrated by the "two-antenna" method. To minimize multipath errors, the gain calibration was performed using multiple distances and with the antennas oriented for both vertical and horizontal polarizations.

D. RADOME LOSS

The pattern and gain of the cross slot antenna were measured without the radome. However, the radome characteristics were evaluated in conjunction with the cavity-backed, cross-sleeve dipole antenna (Ref. 2). The radome loss was measured by observing the relative received signal of the cross-sleeve dipole, as it was illuminated by a circularly polarized wave, with and without the radome placed over the antenna. Only small variations were observed over the entire frequency band, and it was concluded that the radome presents negligible effects.

* Technical report in preparation.

IV. CONCLUSIONS

A full scale, shallow ridged-cavity, crossed-slot aircraft antenna has been developed for a flight test evaluation via an air-satellite communication link. The antenna is capable of operation from 240 to 400 MHz. The cavity has a 33-in. square base and a 4.18-in wall height.

The electrical characteristics of the slot were measured on a 9.5 x 9.5-ft cylindrically curved ground plane with a radius of 6 ft. The curved ground plane simulates a section of the fuselage of a KC-135 type aircraft. The radiation characteristics will be modified by the vehicle configuration when the antenna is mounted on an aircraft; however, the wideband response of the antenna is expected to be retained.

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